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Geospatial Evaluation of Land Use and Land Cover Changes in Ashulia Industrial Hub in Dhaka, Bangladesh

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Abstract

Spatial and temporal evaluation of the land use and land cover (LULC) changes, its dynamism and overall consequences are considered the fundamental variables in global climate change. These immense changes influence ecosystem, life, and livelihoods. Over the last few decades, industrial expansion in Bangladesh has a major effect on LULC across the suburban areas of the capital city Dhaka, especially the surrounding areas of Ashulia industrial hub. While providing new approaches to improve the frontiers of antecedent revolutions, particularly those of LULC changes monitoring and mapping, this study tried to evaluate further land development and planning in the study area between 2014 and 2020. Remote sensing imageries and relevant multiple secondary information were consecutively used as datasets. The interactive supervised classification tool using a maximum likelihood process was applied in LULC changes evaluations, detections, and as well providing fruitful explanations. Therefore, evaluated LULC maps' overall accuracies were between 84% and96%, and kappa coefficient between 0.83 and 0.92. The results revealed that the urbanization and built-up area were the prime LULC type (77.36% in 2020) in the study area and were exceedingly increasing land cover type over water bodies, bare land and vegetation. Overall, in between 2014 and 2020, the LULC types as of water bodies, barelands, and vegetation have decreased by 212 hectares, 435 hectares, and 470 hectares, respectively. Moreover, overall downward trends of LULC changes were identified in all the land use types except built-up area. Hence, imbalanced land conversions and lack of proper planning together were creating the region highly vulnerable to several disasters as well as imbalanced ecosystem. Th study findings can help the decision makers and planners apart from future research.

Keywords

Land use and land cover changes; Industrial expansion; Landsat; Remote sensing; Ashulia

Introduction

Land use and land cover (LULC) changes have been considered as the crucial element of regional changes (Roy and Roy, 2010; Islam *et al.*, 2019; Ghosh *et al*. 2020). The observable magnitudes, varieties, and the geospatial surface variability have made the quantification and assessment of LULC changes the big challenge to researchers (Islam and Ma, 2018; Ganguli, Islam and Garai, 2018; Zhu *et al.*, 2020; Alauddin *et al.*, 2020). However, most of the LULC changes are directly influenced by human activities, and hardly ever follow usual ecological theories (Ghosh *et al.*, 2020; Islam and Roman, 2019; Rifat *et al*., 2021). Theoretically, land use is described as man's activities, while the land cover is described as surface distribution (Roy and Giriraj, 2008). However, remote sensing is considered as the useful process that assists in realizing the changes related to LULC properties with reference to geo-registered multi temporal data products. The usages of remotely sensed data are considered mostly accurate and more appropriate than other sources to identify changes in LULC. Hence, the system is very effective for assessing the change or degrading trends of any regional distribution as well as larger area (Olaleye, Abiodun and Igbokwe, 2009). The incorporation of remote sensing (RS) and geographical information system (GIS) together can assist analyzing land cover mapping, changing detections, as well as trend analysis over the time in variety of ways (Lambin, 2001; Islam *et al.*, 2020). From 1970 to 2020, the population of Dhaka metropolitan (DMA) has reached from 1.4 million to 21.7 million that has grown it into a crowded metropolis and one of themost quickly urbanizedcities in the world (The World Bank, 2021). Several studies have suggested that if the trends of population growth continue, together with industrialization and the ever-increasing economic growth expected to occur over the next 10–15 years, DMA would rise up as the 6th largest urban cluster on the planet (Hassan and Southworth, 2018). The estimated risen up urban cluster level already achieved in 2021 as the DMA cluster population is now 6th ranked in the world and 4th in Asian continent with 3.50% growth rate (The World Bank, 2021). Influx of rural migrants is primarily inflated by this vast and rapid urbanization and industrialization driven by population growth in capital city Dhaka (Elahi, Rashid and Sarkar, 2016). Either looking for employment in a thriving industrial sector, like textile and readymade garments around the city, or to avail themselves modern civic facilities, like job, recreation, park, health care clinics, education, and so on, rural people immigrate to the urban centre (Islam and Roman, 2019).

The acceleration rate of population growth in and around DMA creates a tremendous pressure on city lands, infrastructures, as well as urban services (UN-Habitat, 2016). Hence, the respective authorities' altogether have prepared a comprehensive plan and, therefore, initiated to build several industrial zones in the surrounding fringe areas of DMA. Though the implementation procedures were so difficult, most of the specialized industries already shifted their respective locations. The Ashulia industrial hub located in Ashulia union under Savar Upazila in Dhaka district was considered as one of the highly efficient zones that established textile and readymade garments (RMG) industries. The respective area was concerned under selection has several advantages including huge vacant lands, rare flooding, excessive manpower and developed transportation network as we as just lying outer circle of DMA. As a developing peripheral area, Ashulia union has a great efficiency and potentiality to be established as a well-designed industrial town. The geographical location, physiographic character and multiple communication accessibilities have influenced the area to catch speed over a broader scale. Moreover, the study area is also included under the jurisdiction of the country's Capital City Development Authority locally named as 'Rajdhani Unnayan Kartipakkha (RAJUK)'since 1989. It has received further impulse to grow a rapid manner. The potentialities of land use and its transformation in the West and Northwest fringe of the city of Dhaka will be explored further. This area is not different from any other region, but after the construction of "Asian Highway" in 1996, a remarkable change is observed here that modified the prospects of this region. This road promotes international trade and multidimensional advantages and socio-economic development of this region.

Bangladesh has traditionally been observed with the urbanization processes as the result of economic development and population growth. Very little work has been done to track the dynamic growth trajectory in a spatial or physical context (Hassan and Nazem, 2016). A wide range of socioeconomic, climatic, physical, biologicaland hydrological systems is affected ultimately by the LULC changes where LULC change is the key modifier of the landscape (Sohl and Sohl, 2012; Oliveira *et al.*, 2012). The rapid changes of LULC, specifically in developing nations, are often characterized by drastic urban sprawling (Jat, Garg and Khare, 2008; Mundia and Aniya, 2006). In addition, the transformation of farmland to shrimp farming (Ali, 2006) is impending huge cost to the environment (Abdullah, 2005) or land degradation by construction infrastructure, agricultural development and tourism industry (Malte, Helge and Shalabh, 2007). In one hand, a number ofindustries and residential buildings are being established here. Due to the impact of advanced communication systems and transportation network, rapid land use changes, reduction of agricultural land, development of local economy, increase of employment opportunities, increase of demand for land can be seen in this area. Because this area is located within the jurisdiction of greater Dhaka, most of the industries and housing projectsare constructed in this areaalong the highway without following any rules and regulations. Lack of proper planning, management and monitoring, and excessive pollutions are threatening the environment and livelihoods in this area. Therefore, using remote sensing data, this study aimed to evaluate the geospatial LULC changes in the study area, it's directions and multiple impacts and consequences over the environment. However, the evaluations would be helpful to prepare a sustainable management policy for the study area and other peripheral region of developing cities.

Methodology

Description of the study area

To conduct this study, data was collected from Ashulia union, the northwest periphery of the country's capital Dhaka city situated on the left bank of the Turag River and right opposite of Tongi (Figure 1). Geographically, the area is located between 23^{0}52'00" E to 23^{0}56'00" E latitude and 90^{0}16'30" N to 90^{0}21'15" N longitude. The study area Ashulia is a union under Savar upazila of Dhaka district with a total area of 27.16 square kilometers. Huge paddy fields occupy surroundings of the villages, which make it a kind of tourist attraction. The study area is considered one of most migrant populated areas in Bangladesh. Due to excessive population pressure and high demand of land, the local people are frequently changing their livelihood pattern through degrading the cultivable land, vegetations, water bodies and open spaces. Overall, the environment is frequently detouring and degrading by various types of pollutions.

Datasets and preprocessing

RS satellite imageries were used to monitor and quantify the geospatial evaluation of LULC changes in the study area by selected years of 2014, 2017, and 2020 (Table 1). Multispectral Landsat 8 OLI/TIRS C1 Level-1 data were collected and downloaded from the USGS Global Visualization Viewer (GloVis) archive (https://glovis.usgs.gov/) (GloVis, 2009). Cloud free images were obtained from similar season to look forward to avoiding variation as much as possible in vegetation phenology. After the acquisition of the images, without using the thermal bands of each image scene in seven bands of OLI8, images were superimposed to form a single multispectral image dataset using the layer stack function. The interactive supervised classification tool using a maximum likelihood process was applied to classify the LULC map (Esri, 2020). The supervised classification as of the image analyst develops the spectral signatures of known categories, such as urban and forest, and then the software assigns each pixel in the image to the cover type to which its signature is most comparable (Eastman, 2001). After defining the area of interest (AOI), the classification was applied in the process. The training sites were selected in agreement with the

Landsat images, Google Map and Google Earth. For producing a more accurate LULC map, the classified images were modified with the help of visual interpretation and image indices. Based on IGBP-9, Food and Agriculture Organization (FAO) land cover classes and visible land cover of the study, a classification category was adopted consisting of 5 first level classes, namely water bodies, bare land, vegetation, agricultural land, and built-up areas (Table 2) (Islam *et al.*, 2019). The datum of WGS84 and Zone 46N was selected by the Universal Traverse Mercator (UTM) system as projection for all datasets.

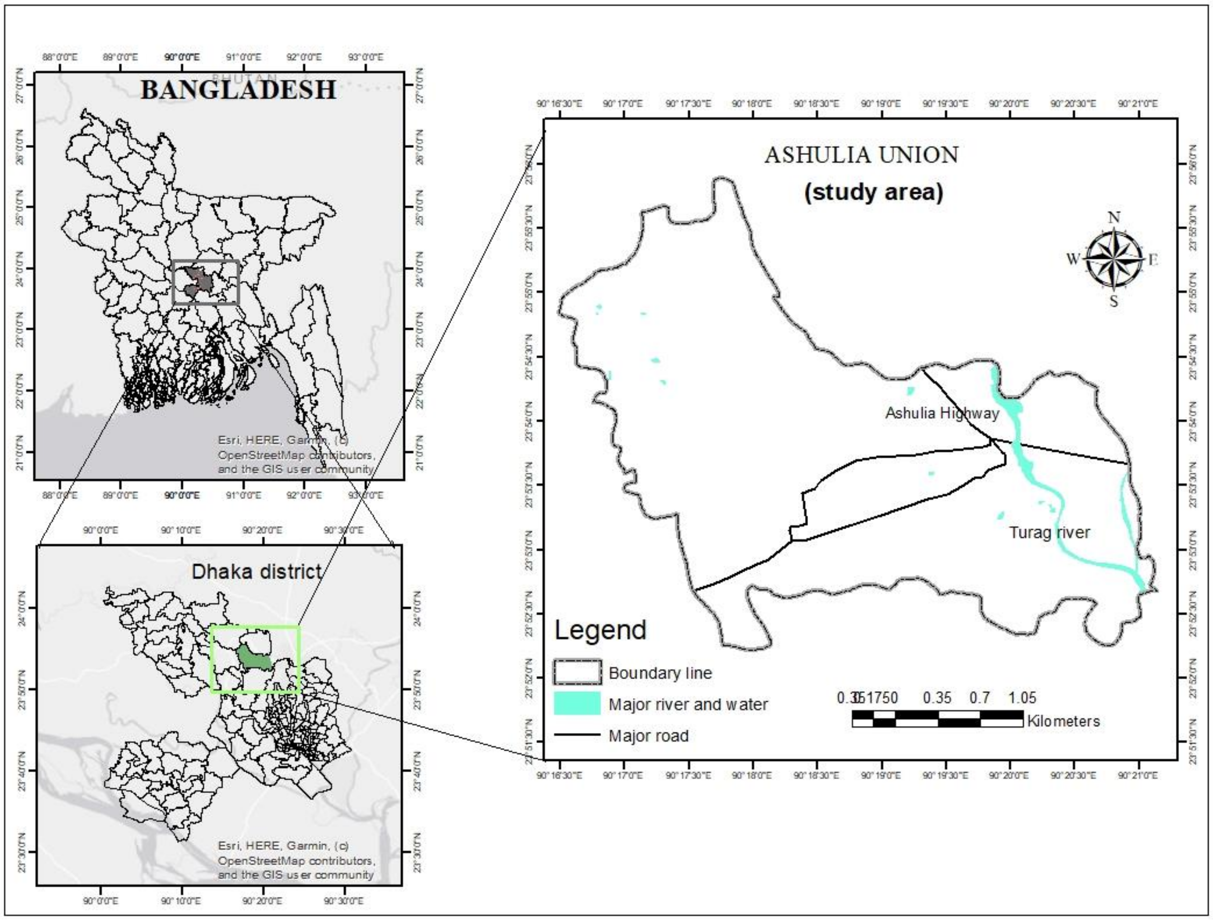

Figure 1: Geographical location of the study area in Bangladesh

Each thematic data layer in the composite data layer as indicated by particular features color and revealed area statistics in the map. The flow chart (Figure 2) described the methods and methodology of the study.

Moreover, some necessary data and information were collected from the primary and secondary sources from direct field observations, conference proceedings, published materials such as books, journals, thesis, etc. The archived both government officials and non-government organizations (NGOs) recorded and published literature, books, journal, and reports were used to prepare the conceptual framework in the study.

Table 1: Characteristics of datasets used in the study

Datasets	*Year*	*Acquisition*	*Spatial Resolution*	*Source*	*Format*
Landsat 8 OLI/TIRS	2014	25 Jan 2014	30m	U.S. Geological Survey	Raster
	2017	17 Jan 2017	30m		
	2020	26 Jan 2020	30m		

Table 2: Land use types of classification process used in the study

Land use types	*Description*
Water bodies	Permanent open water, ponds and reservoirs, ditches, permanent and seasonal wetlands, marshy land, aqua fishing, low-lying areas, lakes
Bare land	Barren land, uncultivated land, open space, earth and sand land in-fillings, construction sites, excavation sites, bare and exposed soils
Vegetation	forest, homestead vegetation, bush and shrubs
Agricultural land	Land used for farming, paddy field, vegetables, agriculture, fruits and other cultivated lands
Built-up area	Residential, industrial, transportation infrastructure, mixed urban and other urban, commercial and services

Accuracy assessment

A cross-validation test was estimated in Random Forest internally during the bootstrapping process used 70% of training data and OOB error estimation used the remaining 30% of training data (Hastie, Tibshirani and Friedman, 2009; Janitza, Tutz and Boulesteix, 2016). However, self-testing is possible to assess model performance. The LULC accuracies evaluate from random sampling techniques. Moreover, the adequate number of validation data points for each class category point out for accurate assessment and a statistical error matrix (Congalton and Green, 2009). Google Earth's high-resolution imagery was used for collecting ground truth samples. Then, ground points were selected manually, which were cross validated with the LULC map using 70 stratified random sample points. Therefore, error matrix calculated overall accuracy between 84-96% and kappa coefficient between 0.83-0.92 that achieved highly acceptable for further assessment and analysis.

$$\text{Overall Accuracy} = \frac{TotalNumberofCorrectlyClassifiedPixels(Diagonal)}{TotalNumberofReferencePixels} \times 100 \quad (1)$$

$$\text{Kappa coefficient (T)} = \frac{(TS * TCS) - \sum(columntotal * rawtotal)}{TS^2 - \sum(columntotal - rawtotal)} \times 100 \quad (2)$$

Where, *TS* is the total sample points that considered for accuracy assessments and *TCS* is the total correctly classified sampling points that evaluated.

Results and Discussions

Arial and spatial pattern of LULC in the study area

In this study, the total area of Ashulia Union was calculated as 2,716 hectares (Table 2). The LULC changes and evaluations were designed both from remote sensing data and physical interface therefore (Figure 2). The evaluated LULC of the year 2014 revealed that about 33.51% of the total area was under built-up area because of the location near the Dhaka city. Various residential areas, industries, communication facilities were developing within this area (Figure 3). Only 10.86% area was underwater bodies, categorized as the lowest land covered type. Since urbanization is a continuous process, its rate would be lower than that of the present days. Usually, a large proportion of the land would remain exposed in the past. It was observed from the image of 2014 that about 16.79% of the area was exposed at that time. Besides this, about 846 hectares vegetation cover and 209 hectares agricultural land were present combining nearly 39% of the total area. During this period, deforestation occurred in the current Tangabari, Rangdhanu and Shutingbari areas. In 2017, the highest percentage of land (59.06%) was devoted to the built-up area. Bare lands covered 8.36% of the total area, especially in the north-western and north-eastern part of the union in a scattered way. While vegetation covered about 19.48% areas mainly located in the north-western part and a big proportion was in the central part of the union.

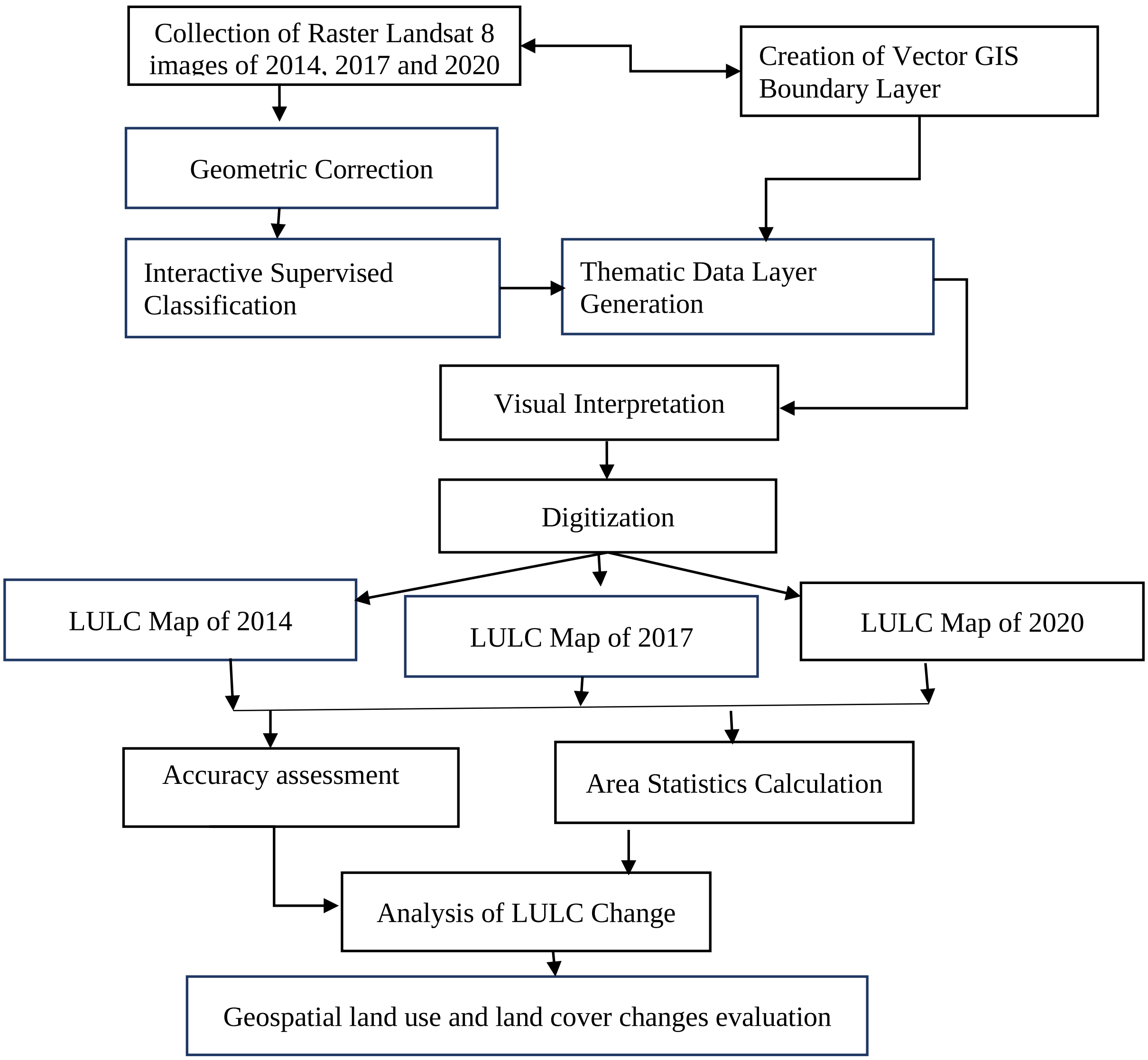

Figure 2: Flowchart of the study

There was a chunk of water bodies (5.56%) at that time. The spatial pattern of the LULC in 2017delineatedvast zones of built-up area. In fact, built-up areas had become consolidated in the period and extended outwards to the north-east and north part of the union. Most of the areas in the south were also filled-up as built-up areas. Built-up area and agricultural land jointly covered almost 66.61% of the total area in 2017. Due to the increase in built-up areas, the bare land had decreased in this part of the

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union. In 2020, the highest percentage of land was also possessed by built-up areas (77.36%), followed by vegetation (13.84%), and bare land (5.68%). A small portion (3.06%) was accounted for water bodies. From the spatial map, it was easily visible that, in 2020, vast areas from south to north were under the built-up categories representing a profound urbanization process in Ashulia Union. At the same time, vegetation and bare lands have decreased considerably during this period. Due to rapid urbanization, agricultural lands were reduced by 70 hectares from 2017. It happened because people started to transform their agricultural land into the residential and commercial land. However, overall water bodies in terms of area coverage are prevailed a decreasing trend in Savar Upazila of Bangladesh over this period (SPARRSO, 2020).

Table 2:Areal distributions of LULC types in the study area

LULC Types	*2014*		*2017*		*2020*	
	Area(in ha)	*%*	*Area(in ha)*	*%*	*Area(in ha)*	*%*
Water bodies	295	10.86	151	5.56	83	3.06
Bare land	456	16.79	227	8.36	21	0.77
Vegetation	846	31.15	529	19.48	376	13.84
Agricultural land	209	7.70	205	7.55	135	4.97
Built-up area	910	33.51	1604	59.06	2101	77.36
Total	2716	100	2716	100	2716	100

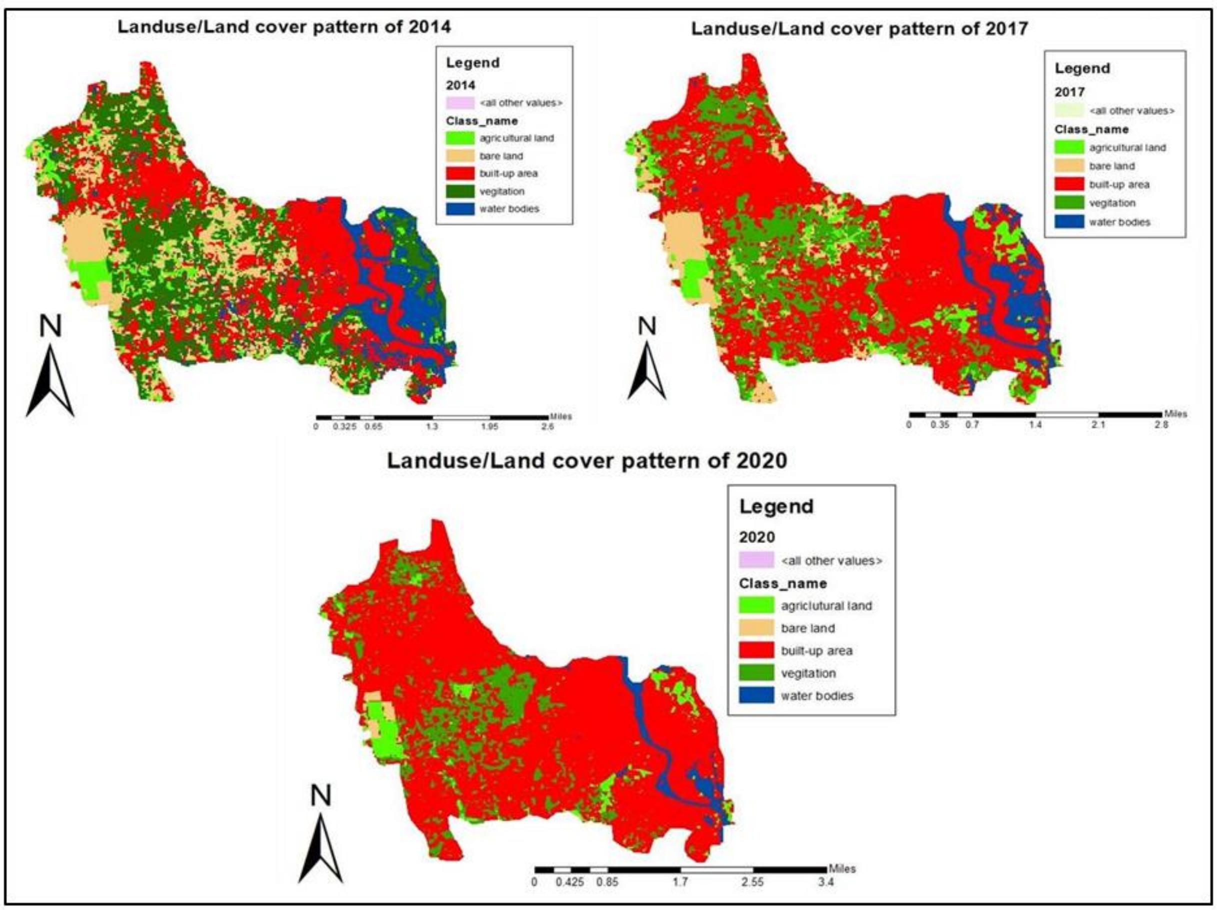

Figure 3: LULC Pattern of the Study Area by 2014, 2017, and 2020

LULC changes detection

LULCC is the transformation of different land use types and is the effect of complex interactions between the physical environment and humans (Pielke *et al.*, 2011; Shalaby and Tateishi, 2007). In global change, LULCC is a major driver and has an effective impact on biological cycles; ecosystem processes and biodiversity (Basommi *et al.*, 2016; Verburg *et al.*, 2004; Begum, Nessa and Alam, 2013).The changes of lands were shown by area in hectare and by percentage in Table 3 to have a clear and obvious understanding on the modification of lands through a notable span of time. However, water bodies in this study were mainly referred to the small ponds, ditches, and canals around the city. The areas of water bodies (Figure 3) had changed more drastically throughout the study period. Overall, the total water bodies in Arial declined about 7.8%, which was mainly the canal encroachment and illegal occupation of water bodies. From the Table 3, it is clear that the area of bare land decreased gradually. During 2014-2017, the area of bare land dropped dramatically about 8.43%, which was the highest throughout the study period. Moreover, in the total time span of 7 years, the decrease was roughly 16% (Table 3). As bare lands occupied by various infrastructure (houses, official buildings, industries, etc.), its reduction rate indicates the increase of urban concentration. For accommodation, people build house without obeying the existing rules and regulations. Influential individuals and local people built their houses for earning money by renting them to the poor and migrant people. As a result, the population increased excessively, due to a large influx of rural work in the thriving industrial sectors in Savar (Islam, 1996; Amin, 1991; Begum, Nessa and Alam, 2013). It is evident that the area of vegetation (Figure 6) had reduced noticeably within the period of 7 years (2014-2020). The rate of reduction had increased year to year and, lastly, it was about 11.67% decline during 2014-2017. Between 2014 and 2017, the vegetation cover decreased significantly (317 hectares). Decreasing in this type of land cover would create a serious environmental effect and would be completely averse to the sustainable environmental development of the area. In 2017, most of the land of Ashulia was being used for industrial purposes. There were vast vegetated area, agricultural land, and vacant land and water bodies. However, in 2017, it was seen that water bodies and vacant land have reduced. Large area has changed to residential and industrial area, which was under agricultural use. These changes have been triggered by rapid population growth. These excessive population demand for more space arising out of swift growth of multistoried building, housing, communication, commerce, industries, food production, market expansion, etc. is going to exert more pressure on land; and this will play substantial roles in land use change of Ashulia in future. The degradation of forests, grasslands, vegetative areas, wetlands, water bodies and bare lands across the whole region occurred due to the fast urban growth. The increasing urban growth is connected to multiple possible factors and drivers, including education facilities, increased job opportunities, natural population growth and social-cultural modern facilities to urban life. However, the increased rural to urban migration significantly results from economic insolvencies, unemployment, natural disasters, landlessness and river erosion in the countryside.

Table 3: Areal changes of LULC in the study area

LULC Types	*2014-2017*		*2017-2020*		*Overall change (2014-2020)*	
	Changes in area (hectares)	*(%)*	*Changes in area (hectares)*	*(%)*	*Changes in area (hectares)*	*(%)*
Water bodies	-144	-5.3	-68	-2.5	-212	-7.8
Bare land	-227	-8.43	-206	-7.59	-435	-16.02
Vegetation	-317	-11.67	-153	-5.64	-470	-17.31
Agricultural land	-4	-0.15	-16	-2.58	-74	-2.73
Built-up area	+694	+25.55	+497	+18.3	+1191	+43.85

N.B.: Positive (+) and Negative (-) figures are showing increase and decrease of an area respectively

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Change detection for water bodies area

In 2014, the area of water bodies was 295 hectares, which has decreased to 151 hectares in 2017 (Figure 3). Therefore, decreasing trends continued and already reached to 83 hectares by 2020. As an industrial area, many people are migrating daily to work in these areas and, thereafter demand of residential as well built-up area grows expanding over water bodies such as rivers, canals, ponds of this area. Therefore, the water bodies have reduced.

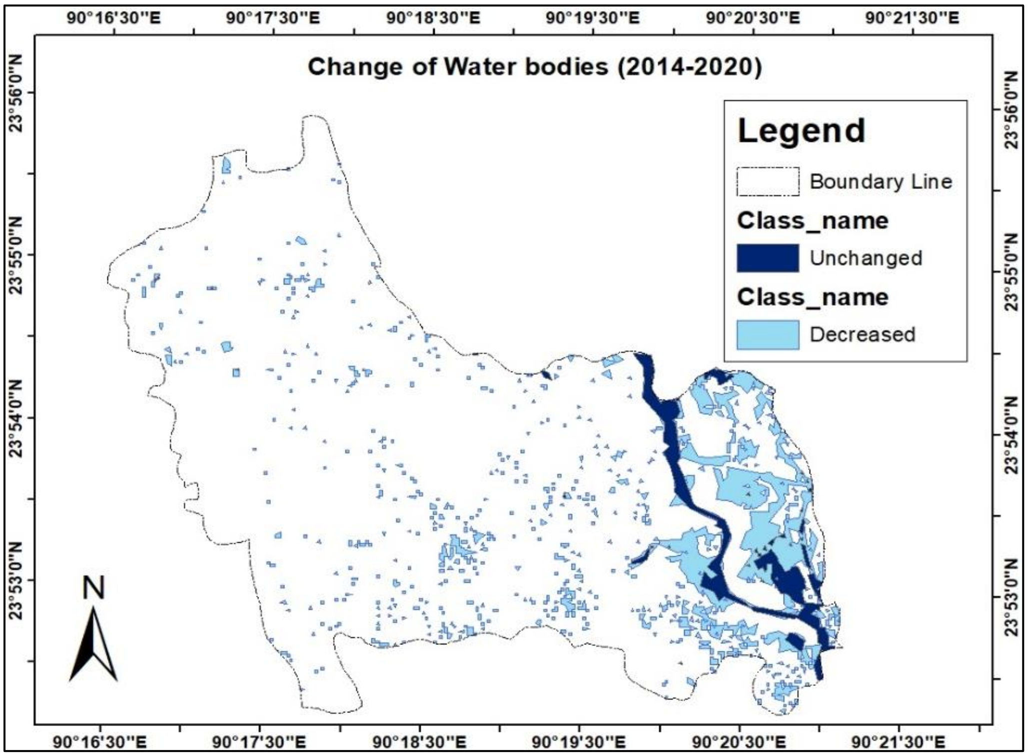

Figure 4: Changing Scenarios of Water bodies.

Change detection for vegetation areas

Ashulia was a green vegetation area one decade ago. The DEPZ industrial area was starting to build up the factories. As a result, the vegetation areas were cleared to make the space. As this research covers the duration between 2014 and 2020, so it has described the deforestation over this time interval (Figure 4). In 2014, the total area under vegetation cover was 846 hectares, which was reduced to 529 hectares in 2017, and in 2020 it reduced to 376 hectares. Therefore, it is noticed that the vegetation cover decreased to create space for new migrants. The change detection for vegetation areas is found out with the help of Google Earth and ArcGIS.

Change detection for built-up areas

Most area of Ashulia is under textile, garments industries. Settlement is the feature that changed most of this area. Figure 5 described that the built-up area in Ashulia in 2014 was 910 hectares. It became 1604 hectares in 2017. Again, in 2020, it raised up to 2,101 hectares. Hence, it is clear that the population of Ashulia area increased at alarming rate. To increase space for the people of this area, the bare land and low landscape was filled up. New houses are built-up.

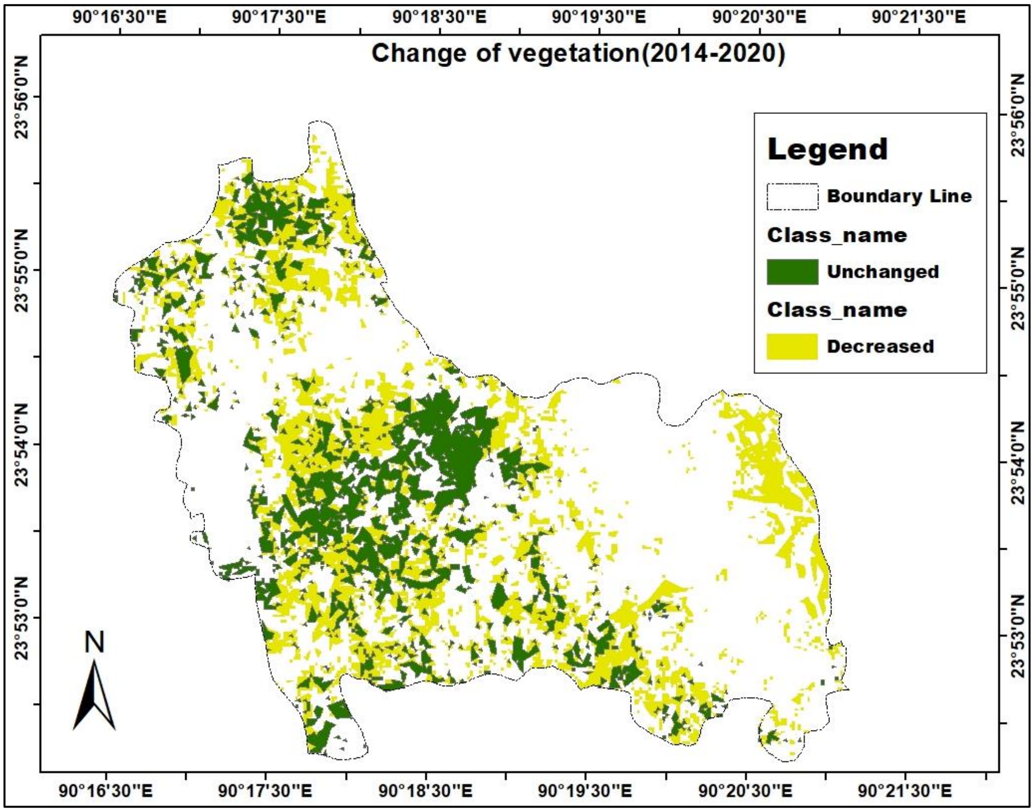

Figure 5: Changing Scenarios of Vegetation

Ashulia is the most important area under Savar upzilla. Dhaka EPZ is situated here. Many people from different districts work in the factories here. LULC change information in the form of statistical data and maps is very important for spatial planning, utilization and management of land. Information for detecting and monitoring changes in land cover and land use are now provided by RS data and analysis techniques. Ashulia area is connected with several important roads and rivers, which influence other areas. Baipail-Tangail highway plays a very significant role on the changing characteristics of the land use pattern in this study area (Elahi, Rashid and Sarkar, 2016). Land use in Ashulia drastically changed in last 10 years. In 2014, most of the area of Ashulia was used for fishing, agricultural as well as brickfield purposes. Most of the people were poor and farmers. They cultivated different types of vegetables in high land and rice in low land area. The major findings of the study are trend of population changing, socio economic changing, socio economic development trend on Ashulia (from 2014-2020). The land use transformation process in Ashulia has started due to industrial expansion; it took place along the Baipail-Tangail highway.

The community is facing numerous problems due to unplanned growth and expansion of industrial, settlement and commercial establishment, which are influencing present physical, socio-economic and environmental conditions. To overcome the shortcoming related to deviation of environmental degradation, agriculture land, hostage of utility facilities, lack of active supervision of regulation for industries, lack of monitoring system, lack of public open space and health care centers etc., some steps should be taken. It is noticed that there has been a rapid growth of regular sub-urban settlements in Ashulia over the last few decades due to high demand for housing. Urban to suburban migration and rural to urban migration are responsible for the increasing housing demand in this area. Infrastructure like gas, road network, and electricity influences the location of these spontaneous haphazard settlements. It is also showed that the growth of these settlements and unplanned development is not sustainable in the long term. For controlling large-scale land use transformation and developing a planned sub-urban township in

Ashulia, government agencies and authorities should play a significant role in term of policy formulation and proper implementation. Besides, monitoring and annual auditing system should be directly exercised by RAJUK. To promote sustainable development activities, public awareness building to enhance environment, NGOs should play a significant role. Therefore, a comprehensive and integrated planning and, thereafter proper implementation, would build Ashulia as a sustainable sub-urban center.

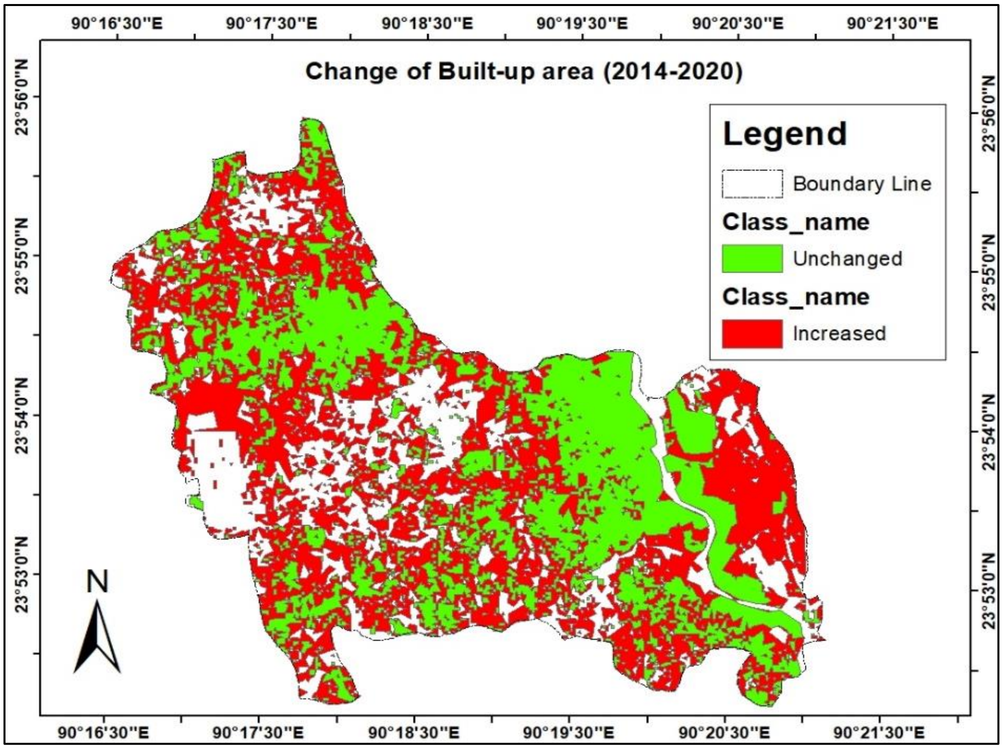

Figure 6: Changing Scenarios of Built-up area

Conclusion

Land use alterations are the fueling factor for population concentration and urban expansion in the urban areas, which are distinct causes for creating various economic, societal and environmental problems. Ashulia and its surrounding zones have faced rapid urbanization, which has resulted in noteworthy changes in land use and land cover over the 7 years period. The outcome of this research reveals that Ashulia is indicating the urban sprawl as the transformation of lands into the built-up area has been going on. The rapid and high rate of decline in barren land and vegetation cover is pointing to environmental deterioration and ecological imbalances. The successful outcome of this study will effectively help to have a sustainable urban planning and management system for the area.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2	Author 3	Author 4
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes
Collected the data	Yes	Yes	No	No
Contributed to data analysis & interpretation	Yes	Yes	No	Yes
Wrote the article/paper	Yes	Yes	No	No
Critical revision of the article/paper	No	Yes	Yes	Yes
Editing of the article/paper	Yes	Yes	Yes	Yes
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Project Administration	Yes	Yes	No	No
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